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Temporal and Spatial Variation in Abundance of Migratory Birds at Kennesaw Mountain, Georgia

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by

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Temporal and Spatial Variation in Abundance of Migratory Birds at

Kennesaw Mountain, Georgia.

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ABSTRACT

Migratory birds spend a significant part of each year in transition between their breeding and resting grounds. During this transitional period migrants rely on stopover sites to provide them with the necessary habitat to replenish lost energy stores, rest, and wait for favorable weather conditions before continuing migration. The majority of stopover work related to passerines in North America has occurred along coastal migration routes. Meanwhile, relatively little work has been conducted at inland stopover sites, areas which may be equally important to migrating birds. Kennesaw Mountain is an isolated geographically prominent peak located in the foothills of the southern Appalachian Mountain range that may provide important stopover habitat for migratory birds, as well as enable migrants to regain their desired migratory route during spring migration. The objectives of this research are to determine 1) if Kennesaw Mountain, a seemingly important inland stopover site in north Georgia, is being used disproportionately over the surrounding mountains, and 2) whether use of Kennesaw Mountain is attributable to its geographical prominence or specific features of its habitat.

During the spring months of 1997 and 1998, I used line transects to census migratory birds at Kennesaw, Lost, and Sweat Mountains to detect possible differences in the occurrence of migrants at each site. Censusing began 10 minutes before sunrise and was conducted every two hours thereafter until noon. In 1997, I detected significantly more migratory birds (both the number of individuals and number of species) on Kennesaw and Lost Mountains than on Sweat Mountain. While during 1998, significant differences were detected only between Kennesaw Mountain and Sweat Mountain. In

general, differences in the volume of migration among sites were greatest just after dawn and gradually decreased throughout the morning.

I did not find a significant difference in the overall volume of migrant individuals or migrant species among time periods within each site, however, the general trend for the number of individuals and species richness at Kennesaw Mountain and Lost Mountain was a peak shortly after sunrise followed by a gradual decline throughout the morning. Meanwhile, Sweat Mountain demonstrated little variation in the number of individuals or species richness throughout the morning during either year. However, the variation in weather among days within a site may act to confound these census data. Variable weather conditions had a significant effect on the occurrence of migrants on Kennesaw Mountain. During days with clement weather conditions (i.e., light winds and clear skies) there was a significant decrease in the number of migrant individuals occurring on the mountain throughout the morning. Meanwhile, during days with inclement weather conditions (i.e., heavy fog, strong winds, or rain) there was no temporally significant difference in the number of migrant individuals. Migrants were much more likely to remain on the mountain and continue foraging throughout the morning. These data suggest migrants are not initially attracted to Kennesaw Mountain due to its habitat.

In addition to censusing, I made observations from a small clearing on the southeastern side of Kennesaw Mountain to detect possible morning flight by largely nocturnal migrants. Data from morning flight observations and censusing on Kennesaw Mountain indicate that migrants typically began to approach the mountain shortly before sunrise, although most individuals did not arrive until shortly after sunrise. The peak arrival of migrants occurred within the first hour after sunrise and dramatically declined afterwards. While observations of morning flight were limited to areas between the east and south, migrants predominantly arrived from the SE and rarely from the east or south.

Observational and census data suggest that migrant birds approaching Kennesaw Mountain may be redetermining their desired migratory route following displacement by unfavorable winds. Moreover, these data suggest the initial attractiveness of Kennesaw Mountain to migrants is based upon its geographical prominence over the surrounding areas. Whereas the evaluation of habitat suitability upon approaching each mountain may be secondary and results in an individuals' decision to 1) perceive the habitat is suitable or necessary for stopover and land or 2) determine the habitat is unsuitable or unnecessary for stopover and continue flying until more suitable habitat is found. Results from this study emphasize the need for further investigation of these and other isolated prominent peaks in the southern Appalachian Mountain range to establish their significance to migratory birds.

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CHAPTER 1

INTRODUCTION

Bird migration is a common phenomenon in which individuals undergo annual movements from breeding areas to resting grounds, in many cases winter quarters, and back (Berthold 1996:25-27). These migrations range from relatively short altitudinal shifts along mountain ridges (Dixon and Gilbert 1964; Rabenold and Rabenold 1985) to spectacular long-distance movements of thousands of kilometers (Berthold 1993:76-77). Depending on the extent and duration of travel during the migratory period, migrants are subjected to numerous physiological stresses and hazardous conditions. Migrants must cope with an increased energetic demand due to extended periods of activity, heightened risks of predation, and displacement from their desired migratory route due to unfavorable winds or the inability to orient properly. To meet these demands successfully many migrants undergo periods of stopover during migration. Stopover is a period during which migrants interrupt migration to replenish depleted energy stores, rest, and redetermine (Moore 1990:427) their migratory route if necessary.

Successful stopover involves several distinct behaviors. For example, Moore and Simm (1985) found that in preparation for migration individuals undergo a period of hyperphagia during which time they have the ability to increase their body mass by as much as 33% its premigratory level. Concurrently, migrants often exhibit a preference for food items providing the greatest net energetic value (Moore and Simm 1985) including a dietary shift towards increased frugivory in species thought to be relatively strict insectivores (e.g., *Dendroica virens* and *Seiurus noveboracensis*; Parrish 1997). These dietary shifts help migrants meet the enormous energetic demands of migration.

Nevertheless, migrants are often faced with the possibility of having insufficient stores of water and energy (in the form of fat) to cross large inhospitable areas successfully (e.g. the Sahara Desert) without a period of stopover (Carmi et al. 1992). Lean birds lacking the necessary energetic requirements to cross these large areas using continuous flight will be forced to delay their migration in an attempt to replenish depleted energy stores (Carmi et al. 1992). Migrants in need of replenishing energy stores are faced with the difficulty of finding suitable stopover sites and are frequently forced to land in unfamiliar and unfavorable habitat, particularly those individuals experiencing their first migration. Moreover, migrants must deal with the possibility of finding insufficient prey availability for refueling during stopover due to competition and seasonality of prey (Schneider and Harrington 1981). In addition, the more fat depleted a migrant has become the more likely it will have to lengthen its period of stopover (Moore and Kerlinger 1987; Yong and Moore 1993; Morris 1996) and may therefore be subjected to unfavorable conditions for a longer period of time.

In addition to storing enough fat for migration and finding and exploiting appropriate habitat, migrants will encounter numerous potentially life-threatening environmental factors en route to their breeding or resting grounds. For example, migrants suffer a heightened risk of predation during migration (Lindström 1989) and must compensate for navigational mistakes due to misorientation or disorientation from the desired migratory path (Ralph 1978; McLaren 1981; DeSante 1983). An individual with the inability to orient properly upon outset of its migration or learn correct orientation during migration (Ralph 1978) risks being blown from the desired migratory path due to large-scale weather patterns (Curtis 1969; McLaren 1981; DeSante 1983). Young birds undergoing their first migration appear especially vulnerable to these hazards. In particular, many young birds appear to be incapable of proper orientation and, consequently, drift from their preferred migratory direction, an occurrence that may account for the loss of between 1-10% of fall migrants (Ralph 1978). Stopover can allow displaced migrants to make the adjustments necessary to return to their desired migratory route.

The combination of the physiological stresses and environmental hazards which individuals experience during migration have the potential to significantly lengthen the duration of the migratory period. The lengthening of migration, in turn, may lead to an individual's reduced fitness and possibly, given poor conditions, cause the individual to perish. Therefore, given the need for migrants to find suitable stopover habitat to relieve the physiological and environmental stresses experienced during migration, the study of these areas and how migrants use them is essential to the conservation of migratory birds.

The importance of understanding the impact stopover areas have on migrants is heightened by recent declines in populations of migratory birds. A decrease in the number of North American temperate migrants, birds breeding and wintering north of the continental United States, and Neotropical migrants, birds breeding in North American temperate zones and wintering south of the continental United States (Hunter et al. 1993), has become evident (Hall 1984; Robbins et al. 1989; Askins et al. 1990; Hill and Hagan 1991; Pyle et al. 1994). Habitat loss on the breeding grounds (Holmes and Sherry 1988; Pyle et al. 1994) and the wintering grounds (Marshall 1988; Terborgh 1989) have been suggested as contributing factors to these declines. However, a lack of suitable stopover sites along migration routes may contribute as well (Moore and Simons 1992). Migrants spend up to one-quarter of the year moving between wintering and breeding grounds

(Keast 1980) and rely heavily on stopover sites. Stopover sites provide the necessary habitat in which migrants can rest, fatten, and wait for favorable conditions before continuing migration (Cherry 1982; Moore and Kerlinger 1987; Morris et al. 1994; Morris 1996). While the location of these stopover sites are sometimes difficult to determine, particularly away from the coast, they are critical to passerines during migration.

The vast majority of stopover work related to passerines in North America has occurred along coastal migration routes. Studies along the coast have contributed to our understanding of species, age, and sex related differences in the abundance and timing of migration (Morris et al. 1994; Taylor et al. 1994), rates of mass and fat accumulation (Winker 1995; Morris et al. 1994) and corresponding variation in stopover length (Moore and Kerlinger 1987; Yong and Moore 1993), the ability of migrants to redetermine migratory routes following trans-Gulf flight (Moore 1990), and the utility of morning flight by largely nocturnal migrants (Wiedner et al. 1992). These studies have enabled us to better understand the various seasonal shifts in migratory strategies employed by differing age and sex classes among species along coastal routes. Meanwhile, relatively little work has been conducted at inland stopover areas to develop a similar understanding of migratory strategies. Moreover, most of the inland stopover work which has occurred in North America has been concentrated in fairly localized geographic areas (Winker et al. 1992a, 1992b; Weisbrod et al. 1993). We have only recently begun to understand the seasonal shifts in the habitat use and the timing and abundance of differing age and sex classes by inland migrants (Francis and Cooke 1986; Winker et al. 1992a; Weisbrod et al. 1993; Woodrey and Chandler 1997; Yong et al. 1998). The increase in the demands placed on existing natural resources emphasizes the need to locate inland stopover areas and determine how these resources benefit migrant birds occurring there.

The location of numerous stopover areas, both along the coast and at inland locations, has been partly due to the recognition of the influence geographical features can have on birds during migration (see Vuilleumier 1963). In many instances, geographic features impede migration by acting as barriers that migrants must either circumvent, such as mountain ranges (Berthold 1993) and oceans (Wiedner et al. 1992), or employ specific strategies to cross, such as deserts (Bairlein 1988). There is also evidence that many species of birds use geographic features as flyways during migration. Raptors, for instance, benefit from traveling along mountain ridges which provide an upflow of air. The upflow of air, in turn, creates lift for the birds and enables them to glide great distances with reduced effort (Kerlinger 1989). Likewise, many species of waterfowl are well known for migrating along large river valleys and taking advantage of the resources these systems provide. Moreover, there is evidence to support the notion that many species of passerines use geographic features (e.g., mountain ranges and large river valleys) as flyways (Hall and Bell 1981; Winker et al. 1992a; Weisbrod et al. 1993). While it is evident that migrant passerines are at times abundant along particular geographic features, it is not well established to what extent these features benefit migrants (i.e., do they provide migrants with valuable stopover habitat or are they used primarily for navigation during migration?).

Because the Appalachian Mountains have a northeast-southwest orientation and during spring migrants in this geographical region are known to travel in a similar direction (Gauthreaux 1978), the Appalachians may provide important stopover habitat and act as a leading line for these individuals during migration. "Leading lines are topographical features, usually long and narrow, with characteristics that induce migrating birds to follow them. The birds are influenced by these lines in choosing their direction of flight, being so to speak led by them" (Geyr 1963). Kennesaw Mountain is an isolated, geographically prominent peak located in the foothills of the southern Appalachian Mountain range that may provide important stopover habitat for migratory birds, as well as enable migrants to redetermine and regain their desired migratory route during spring migration. Similar to the isolated Sierra de Tuxtla mountain range in southern Veracruz, México (Andrle 1966), Kennesaw Mountain attracts a high density and wide variety of migratory birds during spring and fall migration, including many species rarely reported from the southern Appalachians (Beaton 1995). The abundance of migrants implies that Kennesaw Mountain may be an important stopover site. Management activities at Kennesaw Mountain are likely to be influenced by this perception. Nevertheless, the abundance of migratory birds on Kennesaw Mountain has never been quantified and little is known about the stopover patterns of migrants occurring there.

In addition to Kennesaw Mountain, several other isolated peaks occur in this immediate region of the southern Appalachian Mountains. However, until recently the occurrence of migrant birds on these surrounding mountains has not been well established. The study of these geographically isolated mountains may provide us with clues to locating other inland areas used by migrants, as well as, help to elucidate to what extent migrants rely on geographic features (i.e. mountain ranges) for guidance during migration. The objectives of this research are to determine 1) if Kennesaw Mountain, a seemingly important inland stopover site in north Georgia, is being used disproportionately over the surrounding mountains, and 2) whether use of Kennesaw Mountain is attributable to its geographical prominence or specific features of its habitat. Overall, this research will assess the significance of Kennesaw Mountain as a stopover site for migratory birds.

CHAPTER 2
STUDY SITES AND METHODS

Study sites. – Kennesaw, Lost, and Sweat Mountains are located in the upper piedmont of Georgia and are part of a series of isolated peaks in the southern Appalachian Mountain range. These mountains are located approximately 435 km from the Atlantic Ocean and the Gulf of Mexico. Kennesaw Mountain (33°58' N, 84°35' W; USGS Marietta quadrangle) is located in the Kennesaw Mountain National Battlefield Park, Cobb County, Georgia, roughly 32 km northwest of Atlanta (Fig. 1). Kennesaw Mountain (elevation 551 m) is a geographically prominent granite outcrop and is surrounded by 1168 ha of largely wooded habitat, mainly deciduous forest. The mean elevation of the area surrounding Kennesaw Mountain is 340 m. Thus, the mountain peak rises roughly 211 m higher than the surrounding area. Lost Mountain (463 m) and Sweat Mountain (512 m), also geographically prominent granite outcrops, are located within 16 km of Kennesaw Mountain. Lost Mountain (33°57' N, 84°42' W; USGS Lost Mountain quadrangle) is predominantly covered by hardwood forest and suffers from the initial phases of residential development. Sweat Mountain (34°4' N, 84°27' W; USGS Mountain Park quadrangle) consists of a mixed pine-hardwood forest and has suffered substantial deforestation due to residential and commercial development.

Line transects. – During the spring months (April - May) of 1997 and 1998, I used line transects to census migratory birds at each of the three study sites. Transects allow coverage of extensive areas in a fixed period of time and create large sample sizes quickly (Bibby et al. 1992). Transects enabled me to census continuously and gave me the

Figure 1. Location of Kennesaw Mountain, Georgia.

mobility necessary to quantify the rapidly moving flocks of migrants at each study site. Transects were 500 m in length and located near the ridge of each mountain (Figs. 2-4). During 1997, each study site was censused at least once a week (n = 8) between 9 April and 20 May. In 1998, Sweat Mountain and Lost Mountain were censused once every two weeks, (n = 3 and 4, respectively) and Kennesaw Mountain at least once a week (n = 10) between 6 April and 15 May. These dates span the peak of migration in this area. Censusing began 10 minutes before sunrise and was conducted every two hours thereafter until noon (three censuses per morning) to assess possible temporal differences in the use of the mountains by migrants. Transects were walked at a pace of 1 km per hour, and all individual migrants either seen or heard were recorded. During the 1-hr censuses transects were walked in both directions with a 5-minute interval in between. To prevent repeated counting of individuals, the direction of the transect walked in which the greatest overall number of individuals was tallied within the hour of censusing was used in the data analysis. Analysis of species richness was based upon the total number of species detected during a 1-hr census period. Classification of whether species were temperate migrants, birds breeding and wintering north of the continental United States, or Neotropical migrants, birds breeding in North American temperate zones and wintering south of the continental United States (Hunter et al. 1993), was based upon statuses set forth by the Southeastern Working Group of the Neotropical Migratory Bird Conservation Program (Hamel 1992). Individuals that were heard in the same location repeatedly or appeared to have established a territory were considered to be nonmigratory individuals and were, therefore, excluded from censusing data.

Morning flight. – The phenomenon in which predominantly nocturnal migrants are observed undergoing flight during the hours shortly after sunrise is known as morning

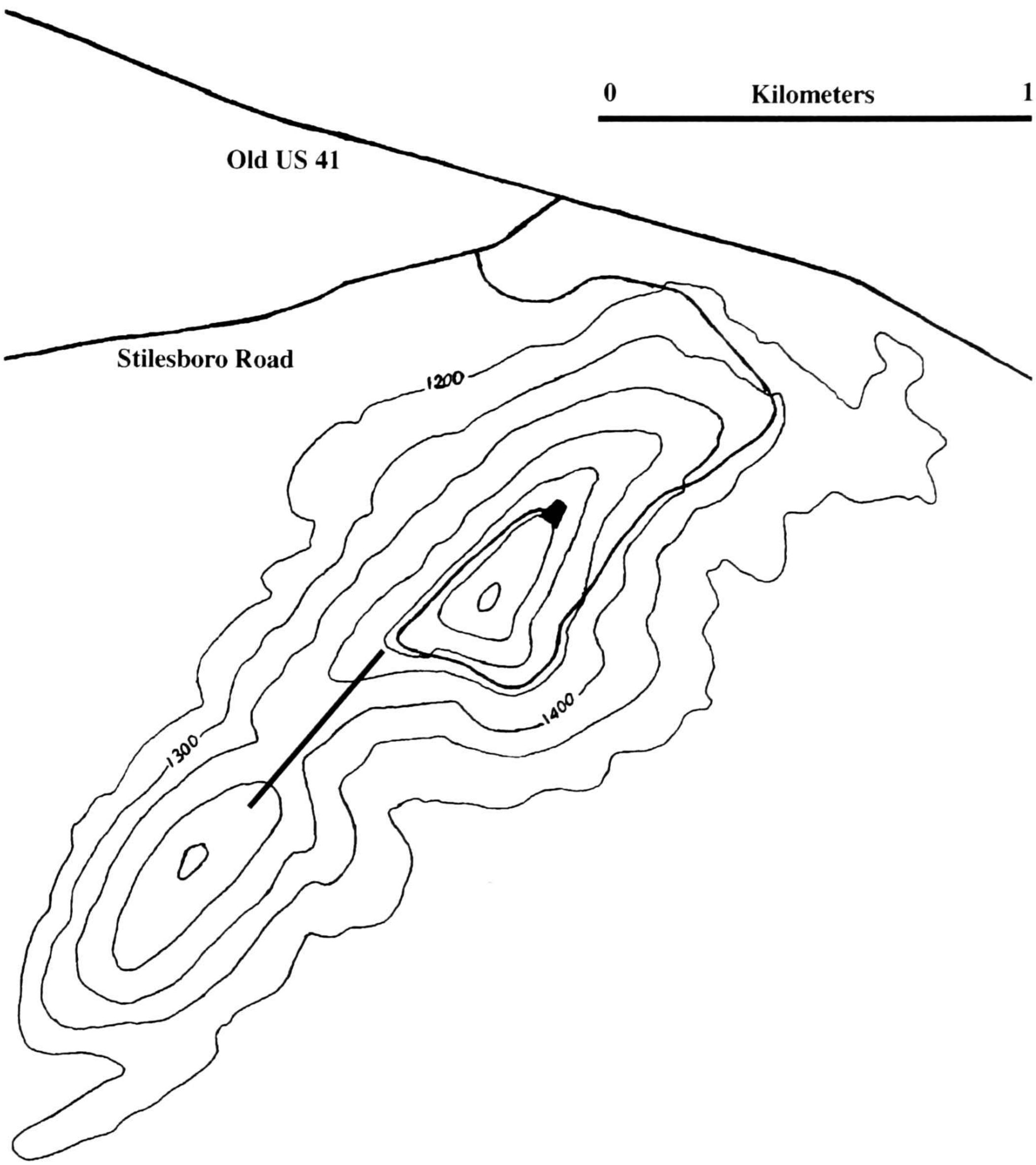

Figure 2. Topographic relief of Kennesaw Mountain, located approximately 32 km northwest of Atlanta in Cobb County, Georgia. Location of the transect is shown by the solid line near the peak of the mountain. The distance between lines is 100 vertical feet (30.5 m). The top of the page is North.

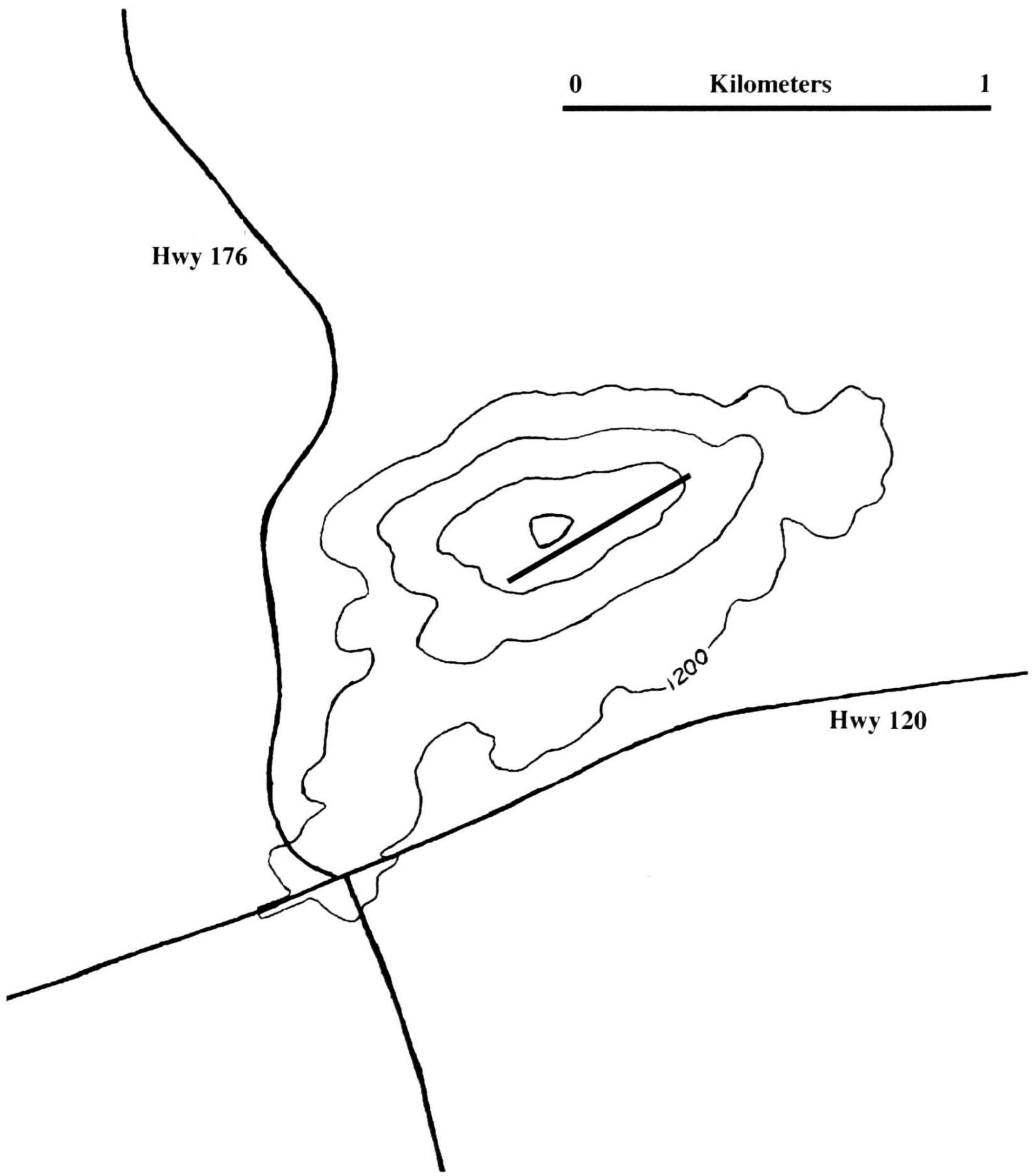

Figure 3. Topographic relief of Lost Mountain, located approximately 35 km northwest of Atlanta in Cobb County, Georgia. Location of the transect is shown by the solid line near the peak of the mountain. The distance between lines is 100 vertical feet (30.5 m). The top of the page is North.

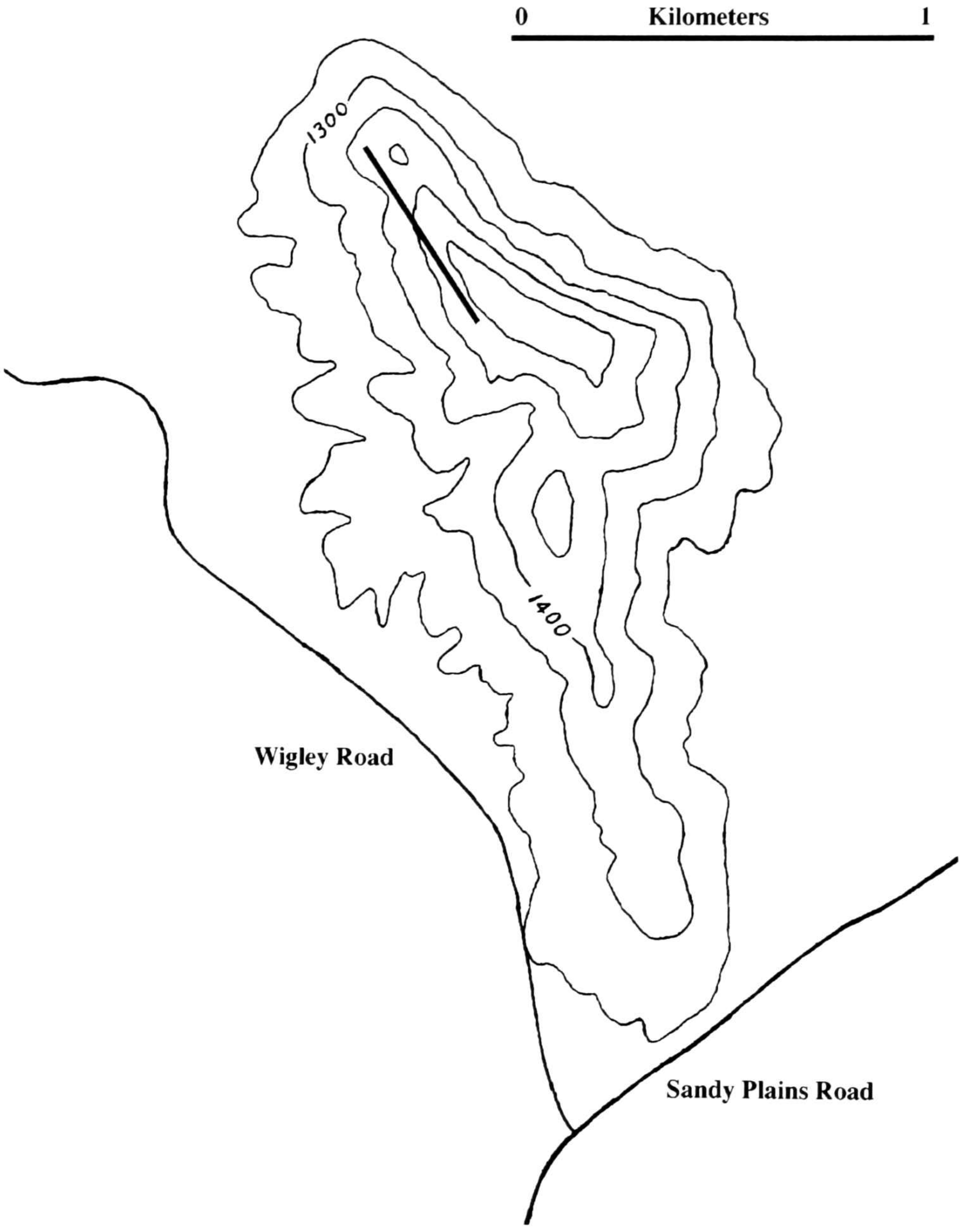

Figure 4. Topographic relief of Sweat Mountain, located approximately 34 km north of Atlanta in Cobb County, Georgia. Location of the transect is shown by the solid line near the peak of the mountain. The distance between lines is 100 vertical feet (30.5 m). The top of the page is North.

flight. I made observations from a small clearing on the southeastern side of Kennesaw Mountain, elevation 457 m, to detect possible morning flight by nocturnal migrants. Three watches were conducted between 4 - 14 May 1998. The clearing allowed for an unobstructed view of migrants arriving between the east and south. Watches were conducted on clear days with a visibility of at least 32 km. Watches began 10 minutes before sunrise and the number of individuals exhibiting morning flight was quantified per 5-minute period. Birds were detected by scanning the horizon with 8x42 Burris roof prism binoculars and by counting individuals as they landed on the mountain or flew overhead. Watches were discontinued when fewer than five birds were detected per 5-minute period. Data concerning wind speeds and directions for the area surrounding Atlanta, Georgia were obtained from NOAA's National Climatic Data Center.

Statistical analysis. -- Data for each of the three study sites were summarized as the number of individuals and number of species detected during each transect. To quantify possible differences in the use among and within each site by migrants, temporal comparisons were made using a one-factor analysis of variance (ANOVA). In order to determine annual fluctuations among and within each site all data between years was analyzed separately. Because the means for particular data sets among and within sites were positively correlated with the variances, I used natural log transformations to cause the variance to be independent of the mean and create normal distributions of these data sets. This analysis was appropriate because the assumptions of normal distributions (Shapiro-Wilks' test for normality) and equal variances (Levene test for equal variances) for this parametric test were met for each data set. Bonferroni corrections were made for multiple tests among sites and among time periods within sites to maintain an experimentwise error rate of 0.05 (Sokal and Rohlf 1995). All statistical analysis was conducted using JMP Statistical Software (SAS Institute Inc. 1995).

CHAPTER 3
RESULTS

In the spring of 1997 and 1998, I censused Kennesaw, Lost, and Sweat Mountains on a total of 41 days. I detected 62 species of migratory birds, 12 species of which were temperate migrants, while 50 species were Neotropical migrants (Appendix). The peak in volume of migration (in terms of individuals and species) across all three sites occurred primarily between 20 April and 10 May (Figs. 5-6).

Among-site differences. - The number of individuals and number of species of migratory birds differed among mountains. In general, the volume of migration did not differ between Kennesaw and Lost Mountains, but both mountains attracted more migrants than Sweat Mountain. During 1997, significant differences in the number of individuals and species richness were detected between Kennesaw and Lost Mountains and Sweat Mountain (Table 1). While during 1998, significant differences were detected only between Kennesaw Mountain and Sweat Mountain (Table 1). I never detected significant differences in the number of individuals or the number of species between Kennesaw Mountain and Lost Mountain.

In general, differences in the volume of migration among all sites were greatest shortly after sunrise and gradually decreased throughout the morning (Figs. 7-14). In 1997, Kennesaw Mountain averaged 37.2% and 79.7% more migrant individuals during the first census than Lost and Sweat Mountains, respectively. Lost Mountain averaged 67.7% more individuals than Sweat Mountain during the same period. During 1998, this pattern was observed again. Kennesaw Mountain averaged 59.3% and 77.5% more

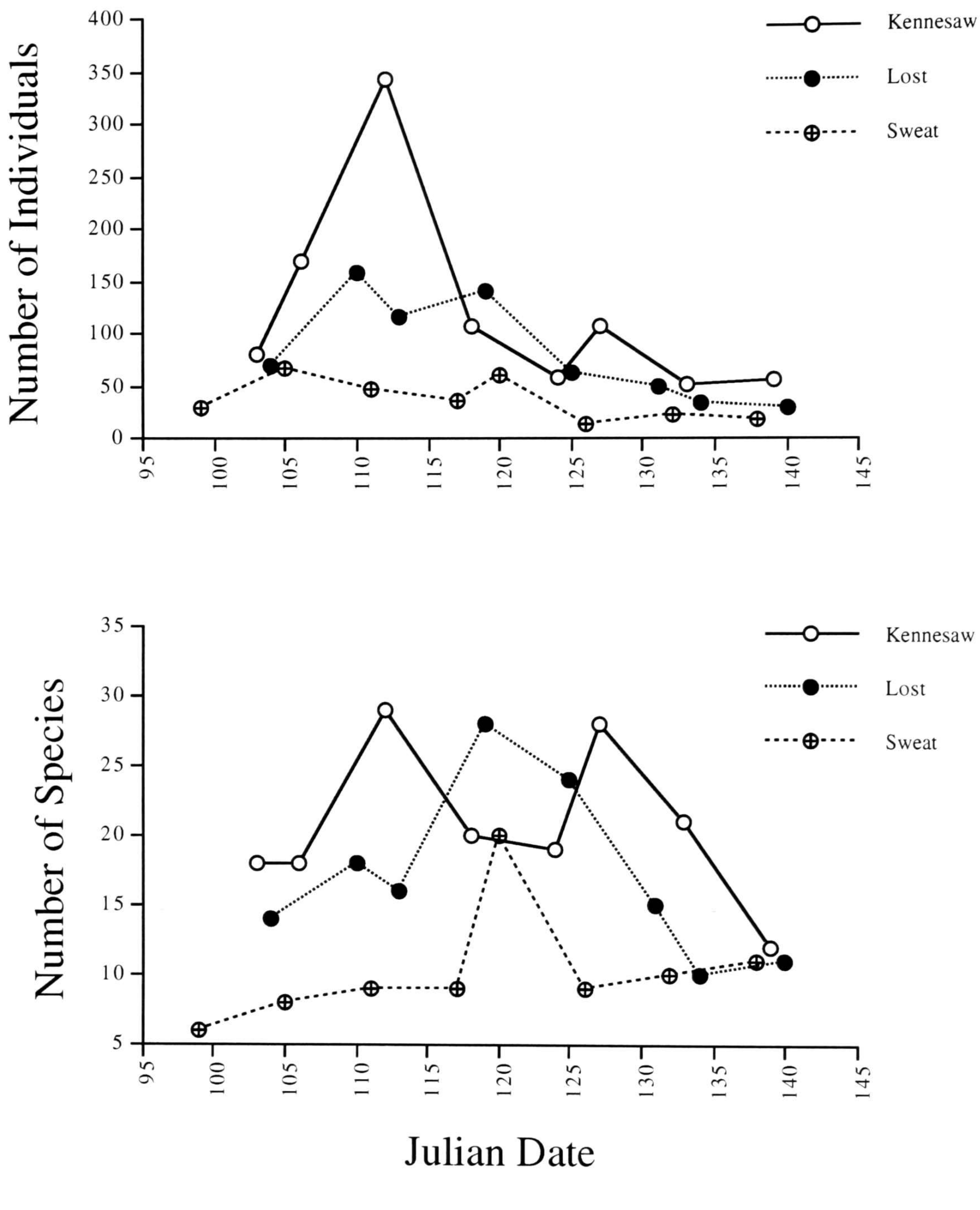

Figure 5. Number of migrant individuals and species per day during spring migration, 1997, on Kennesaw, Lost, and Sweat Mountains in Cobb County, Georgia. Values are based upon the combination of all three censuses during each day. Day 120 = 30 April.

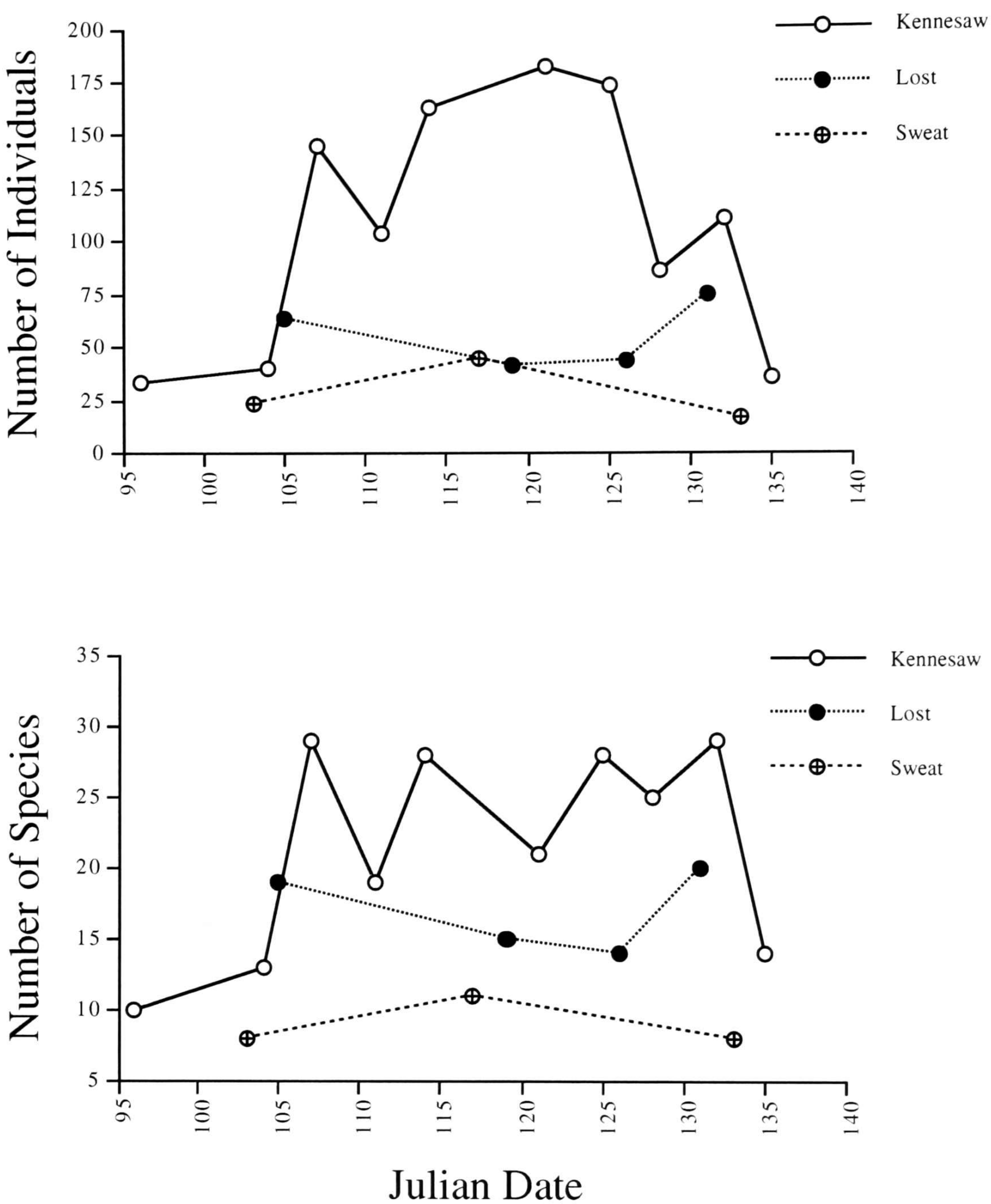

Figure 6. Number of migrant individuals and species per day during spring migration, 1998, on Kennesaw, Lost, and Sweat Mountains in Cobb County, Georgia. Values are based upon the combination of all three censuses during each day. Day 120 = 30 April.

Table 1. Comparison of the differences in the number of individuals and species richness (mean (SE) per site) per census among study sites. Statistically significant differences ($P < 0.05$) among mountains within years are noted by differences in superscripts (^{a,b}). No statistically significant differences ($P > 0.05$) were found between comparisons lacking superscripts.

		Hours After Sunrise					
	Study Site	Zero		Two		Four	
		1997	1998	1997	1998	1997	1998
Migrant Individuals	Kennesaw	57.29 (15.86)^{a}	43.00 (7.86)^{a}	41.50 (15.46)^{a}	37.50 (6.58)	25.43 (8.65)	23.00 (4.09)
	Lost	36.00 (11.12)^{a}	17.50 (2.60)^{ab}	28.13 (5.95)^{ab}	22.25 (4.39)	19.37 (4.24)	16.50 (2.40)
	Sweat	11.63 (2.72)^{b}	9.67 (2.33)^{b}	5.00 (3.45)^{b}	10.00 (6.00)	10.43 (2.36)	9.00 (1.00)
Migrant Species	Kennesaw	17.43 (2.32)^{a}	15.20 (1.96)^{a}	13.50 (1.48)^{a}	15.10 (1.72)^{a}	11.14 (1.99)^{a}	11.60 (1.61)
	Lost	12.25 (1.80)^{ab}	12.25 (1.44)^{ab}	11.25 (1.40)^{a}	11.25 (2.21)^{ab}	9.75 (1.54)^{ab}	9.50 (1.04)
	Sweat	6.63 (1.12)^{b}	6.00 (1.53)^{b}	5.38 (0.98)^{b}	5.67 (2.19)^{b}	6.29 (0.57)^{b}	6.67 (0.33)
Neotropical Individuals	Kennesaw	26.00 (4.05)^{a}	18.10 (3.41)	17.63 (2.22)^{a}	20.70 (3.13)	13.86 (2.08)^{a}	14.50 (2.35)
	Lost	14.25 (1.85)^{a}	12.25 (3.17)	13.50 (1.90)^{a}	15.00 (4.02)	12.13 (2.04)^{a}	10.50 (2.60)
	Sweat	6.13 (1.41)^{b}	4.33 (1.45)	5.00 (0.98)^{b}	6.67 (4.70)	5.57 (0.65)^{b}	6.33 (1.20)
Neotropical Species	Kennesaw	14.57 (2.15)^{a}	11.00 (1.93)	11.13 (1.23)^{a}	12.00 (1.53)^{a}	9.29 (1.69)	9.40 (1.49)
	Lost	9.75 (1.68)^{ab}	9.00 (1.47)	8.63 (1.13)^{a}	8.25 (1.80)^{ab}	7.25 (1.39)	7.25 (1.11)
	Sweat	4.38 (1.10)^{b}	4.00 (1.53)	3.88 (0.64)^{b}	4.00 (2.08)^{b}	5.29 (0.42)	5.00 (0.58)

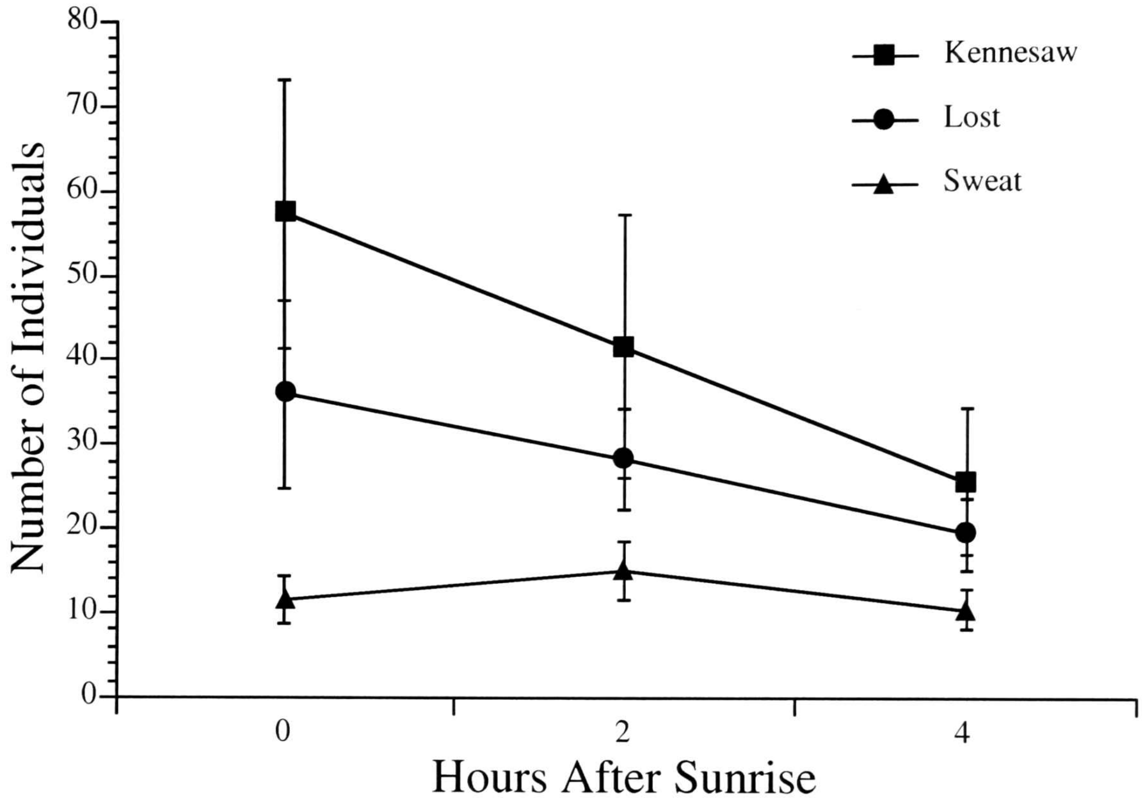

Figure 7. The mean number of migrant individuals (± 1 SE) per census during spring migration, 1997, on Kennesaw, Lost, and Sweat Mountains in Cobb County, Georgia. There was a significant difference in the number of migrant individuals among sites for all time periods combined ($F=15.08$; $df=2,66$; $P=0.00001$).

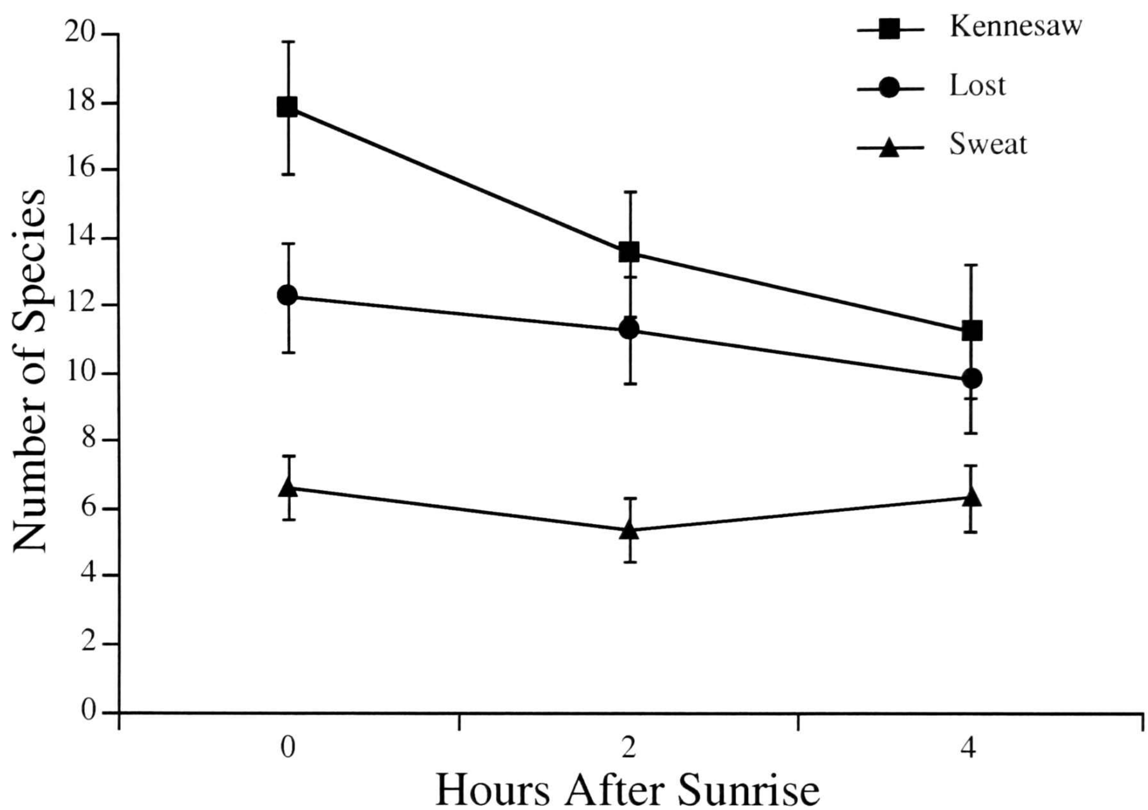

Figure 8. The mean number of migrant species (± 1 SE) per census during spring migration, 1997, on Kennesaw, Lost, and Sweat Mountains in Cobb County, Georgia. There was a significant difference in the number of migrant species among sites for all time periods combined (F=23.67; df=2,66; P=0.00001).

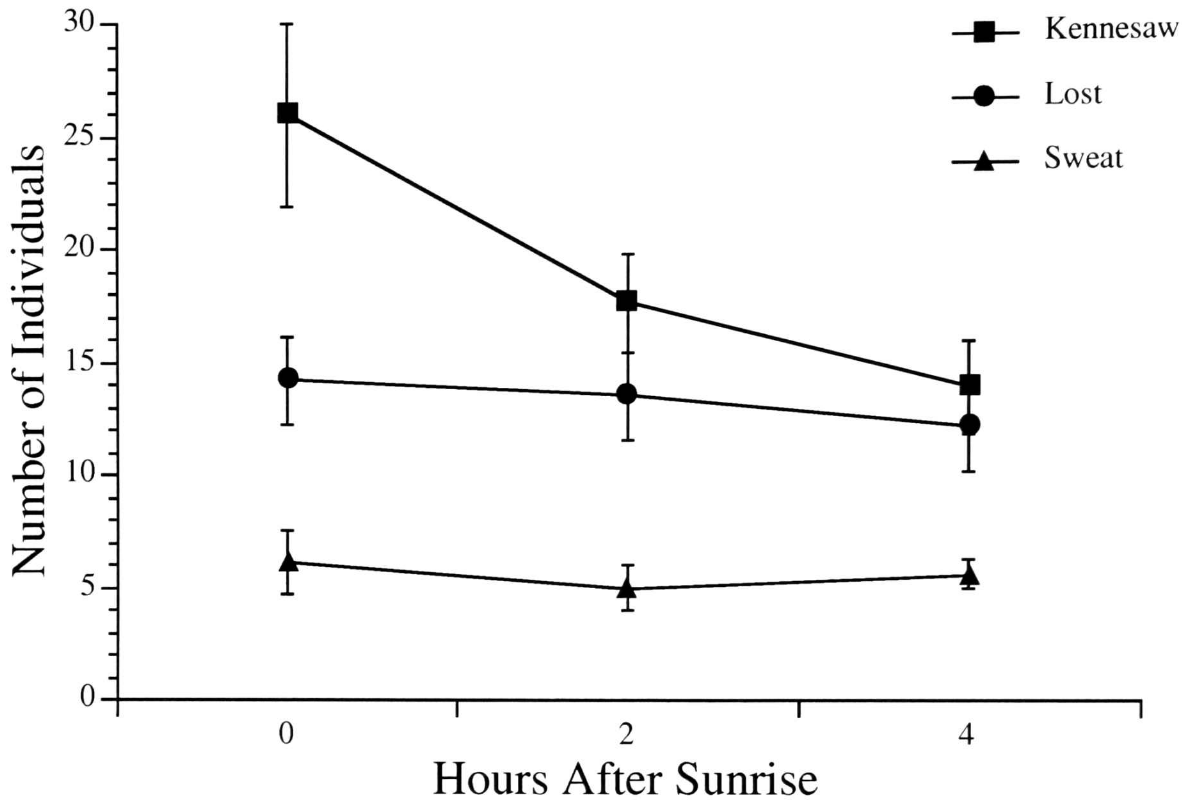

Figure 9. The mean number of neotropical migrant individuals (± 1 SE) per census during spring migration, 1997, on Kennesaw, Lost, and Sweat Mountains in Cobb County, Georgia. There was a significant difference in the number of neotropical migrant individuals among sites for all time periods combined ($F=43.30$; $df=2,66$; $P=0.00001$).

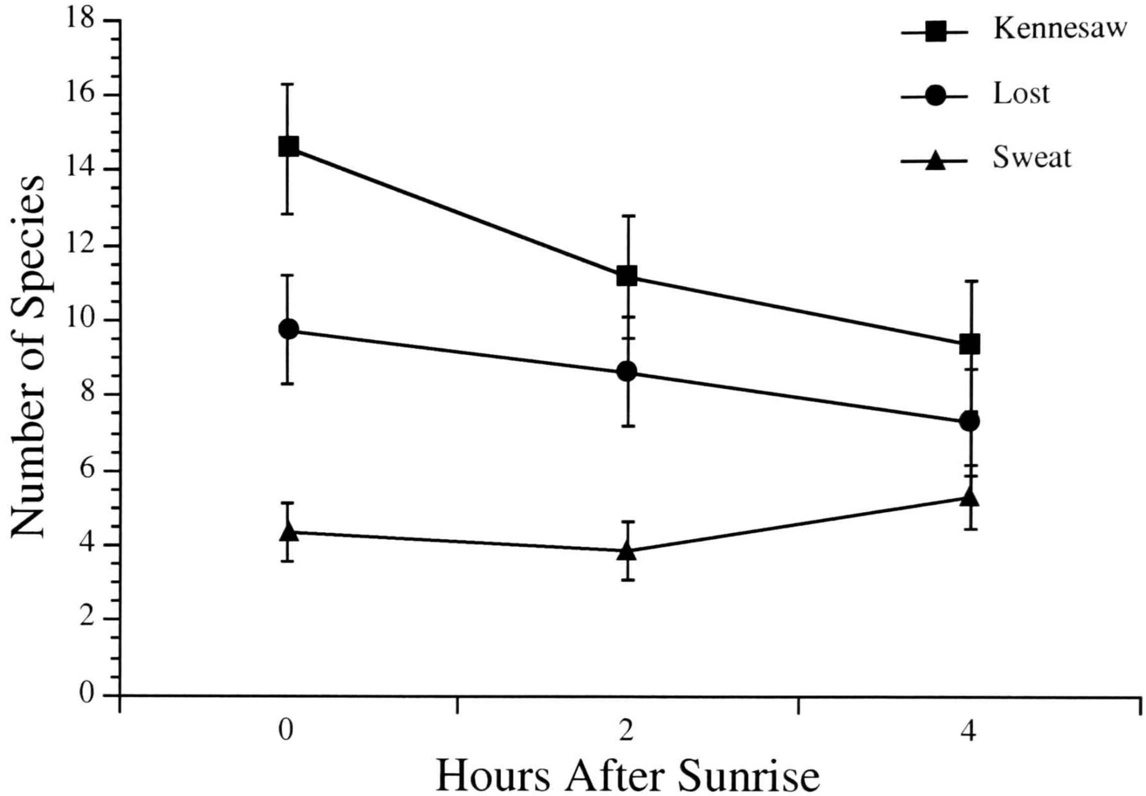

Figure 10. The mean number of neotropical migrant species (± 1 SE) per census during spring migration, 1997, on Kennesaw, Lost, and Sweat Mountains in Cobb County, Georgia. There was a significant difference in the number of neotropical migrant species among sites for all time periods combined ($F=23.75$; $df=2,66$; $P=0.00001$).

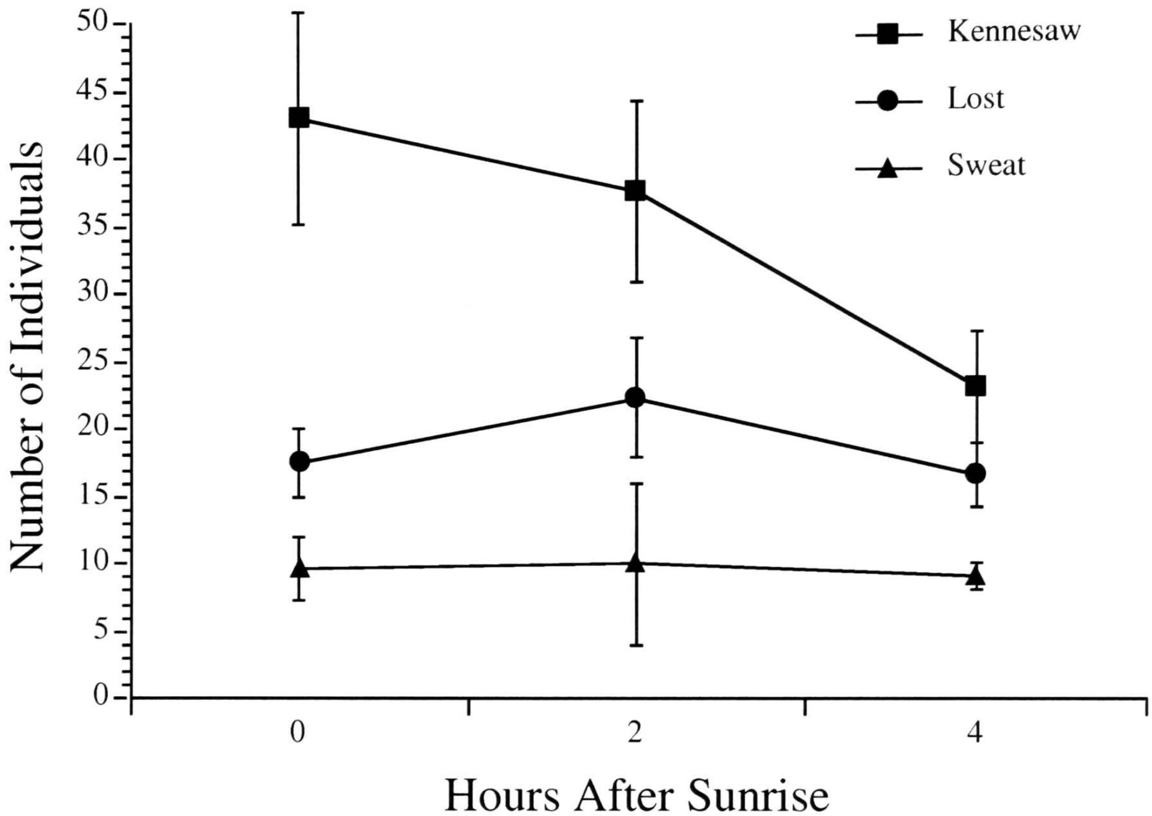

Figure 11. The mean number of migrant individuals (± 1 SE) per census during spring migration, 1998, on Kennesaw, Lost, and Sweat Mountains in Cobb County, Georgia. There was a significant difference in the number of migrant individuals among sites for all time periods combined ($F=13.24$; $df=2,48$; $P=0.00002$).

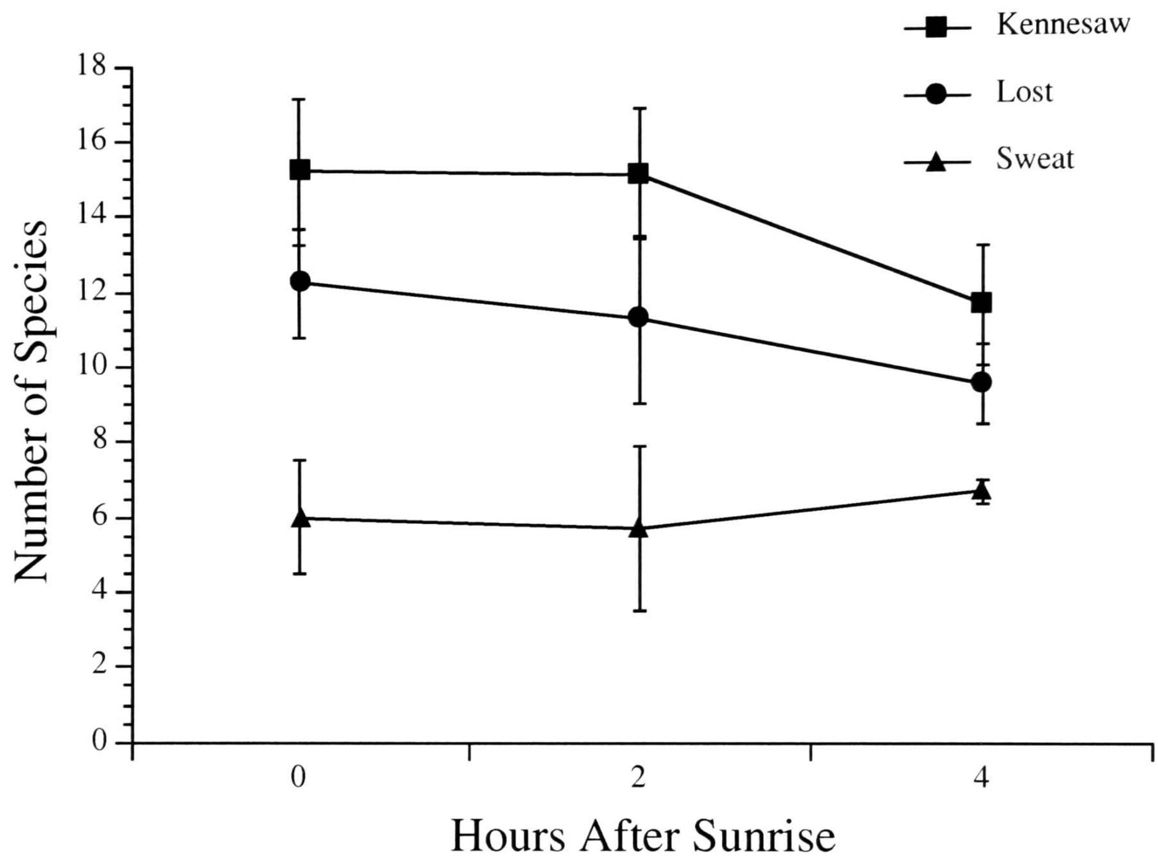

Figure 12. The mean number of migrant species (± 1 SE) per census during spring migration, 1998, on Kennesaw, Lost, and Sweat Mountains in Cobb County, Georgia. There was a significant difference in the number of migrant species among sites for all time periods combined (F=9.71; df=2,48; P=0.0003).

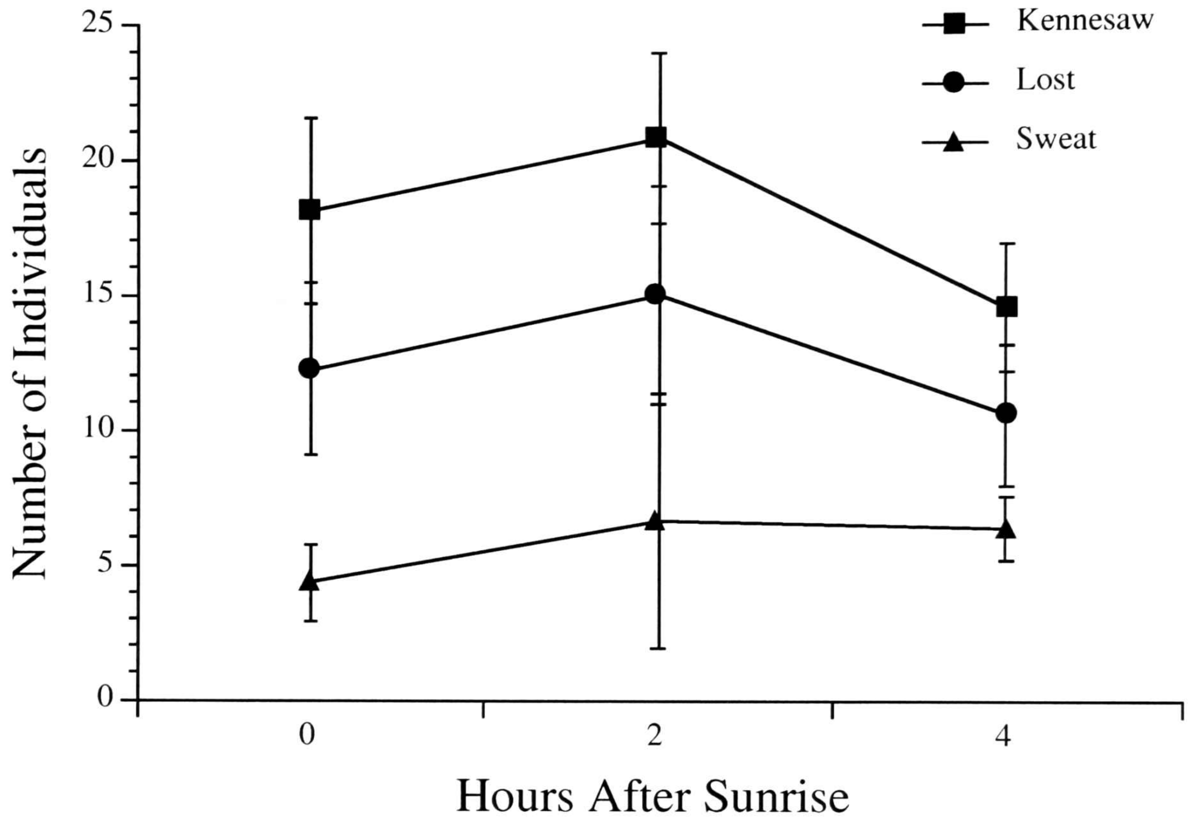

Figure 13. The mean number of neotropical migrant individuals (± 1 SE) per census during spring migration, 1998, on Kennesaw, Lost, and Sweat Mountains in Cobb County, Georgia. There was a significant difference in the number of neotropical migrant individuals among sites for all time periods combined ($F=10.21$; $df=2,48$; $P=0.0002$).

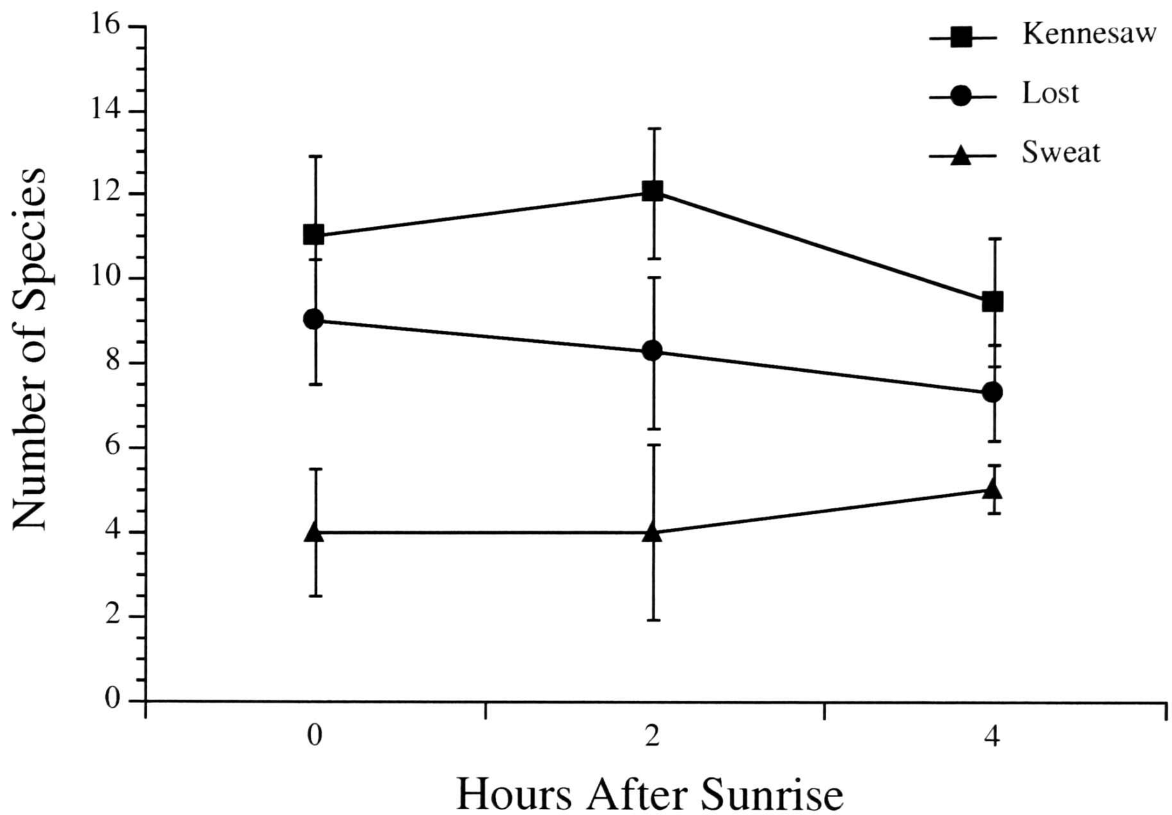

Figure 14. The mean number of neotropical migrant species (± 1 SE) per census during spring migration, 1998, on Kennesaw, Lost, and Sweat Mountains in Cobb County, Georgia. There was a significant difference in the number of neotropical migrant species among sites for all time periods combined ($F=7.96$; $df=2,48$; $P=0.001$).

migrant individuals during the first census than Lost and Sweat Mountains, respectively. Lost Mountain averaged 44.7% more individuals than Sweat Mountain during 1998. However, during 1998 Lost and Sweat Mountains were sampled less frequently than Kennesaw Mountain.

Differences in the number of species detected among sites throughout the entire spring migratory season followed a pattern similar to that observed above. During 1997 and 1998 I detected 48 and 55 species of migratory birds (42 and 48 of which were Neotropical migrants, respectively) on Kennesaw Mountain while censusing. Meanwhile, I detected 40 and 38 species of migratory birds (34 and 29 of which were Neotropical migrants, respectively) on Lost Mountain and 28 and 16 species of migratory birds (21 and 12 of which were Neotropical migrants, respectively) on Sweat Mountain during the same periods. However, during 1998 Kennesaw Mountain was censused more frequently than the other sites, providing additional opportunities to detect species.

Within-site differences. - There was not a significant difference in the volume of all migratory individuals and species among time periods within any site. During 1997, the general trend for the number of individuals and species richness at Kennesaw Mountain and Lost Mountain was a peak shortly after sunrise followed by a gradual decline throughout the morning (Figs. 7-10). During 1998, Kennesaw and Lost Mountains showed a similar trend to the previous spring, although differences between the first and second censuses were minimal, and in some instances there were slight increases (Figs. 11-14). This pattern was not seen at Sweat Mountain. Rather, there was little variation in the number of individuals or species richness throughout the morning during either year. There was a significant difference ($P < 0.05$; ANOVA) between the number of Neotropical individuals during the first censusing period and the third censusing period at Kennesaw

Mountain during 1997 (Fig. 9). No other significant temporal differences (P > 0.05; ANOVA) in the number of individuals or species richness of migrant, or Neotropical migrant, birds were found within any site. However, the lack of a significant decline in migrant individuals throughout the morning at Kennesaw Mountain appears to be influenced by the weather.

To establish the possible effect weather had on migrants upon arrival at Kennesaw Mountain I made comparisons between the number of individuals detected during mornings with clement and inclement weather conditions in 1998 (Fig. 15). During mornings with clement weather there was a significant decline (F=4.96; df=2,29; P<0.01; ANOVA) in the number of migrant individuals occurring on the mountain throughout the morning. Meanwhile, during mornings with inclement weather, there was no temporally significant difference in the number of migrant individuals (F=1.44; df=2,17; P>0.25; ANOVA).

Between years. - There was variation between years in the peak arrival dates (days during which the largest number of individuals occurred) of migrant individuals on Kennesaw Mountain (Fig. 5-6). However, seasonal changes in species richness between years were much more similar and demonstrated two somewhat distinct periods of arrival dates (Fig. 5-6). There was also variation between years in the mean number of individuals and species richness detected during each census on Kennesaw Mountain. Differences may be attributable, in part, to increased inclement weather (i.e., heavy fog, strong winds, and rain) during censuses in 1998 (2 of 8 days in 1997 compared to 5 of 10 days in 1998). In 1998, there was not a sharp decline between the first and second census, in some cases there was a slight increase, and the mean number of individuals during the first census was 25% lower than in 1997. However, the days with the heaviest migration during 1998 demonstrated a much closer pattern to the previous spring (Fig. 16). There

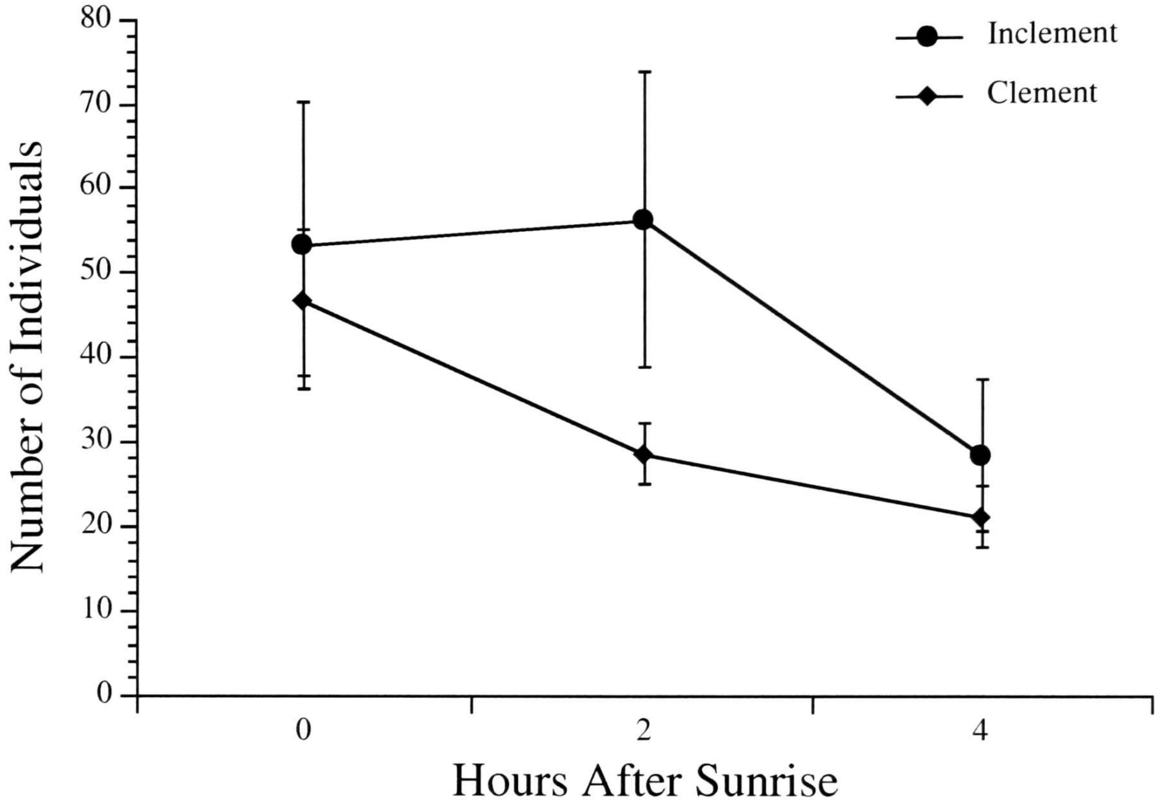

Figure 15. The effect of clement (i.e. light winds, clear skies) and inclement (i.e. strong winds, heavy fog, rain) weather on the number of migrant individuals occuring on Kennesaw Mountain during spring migration, 1998.

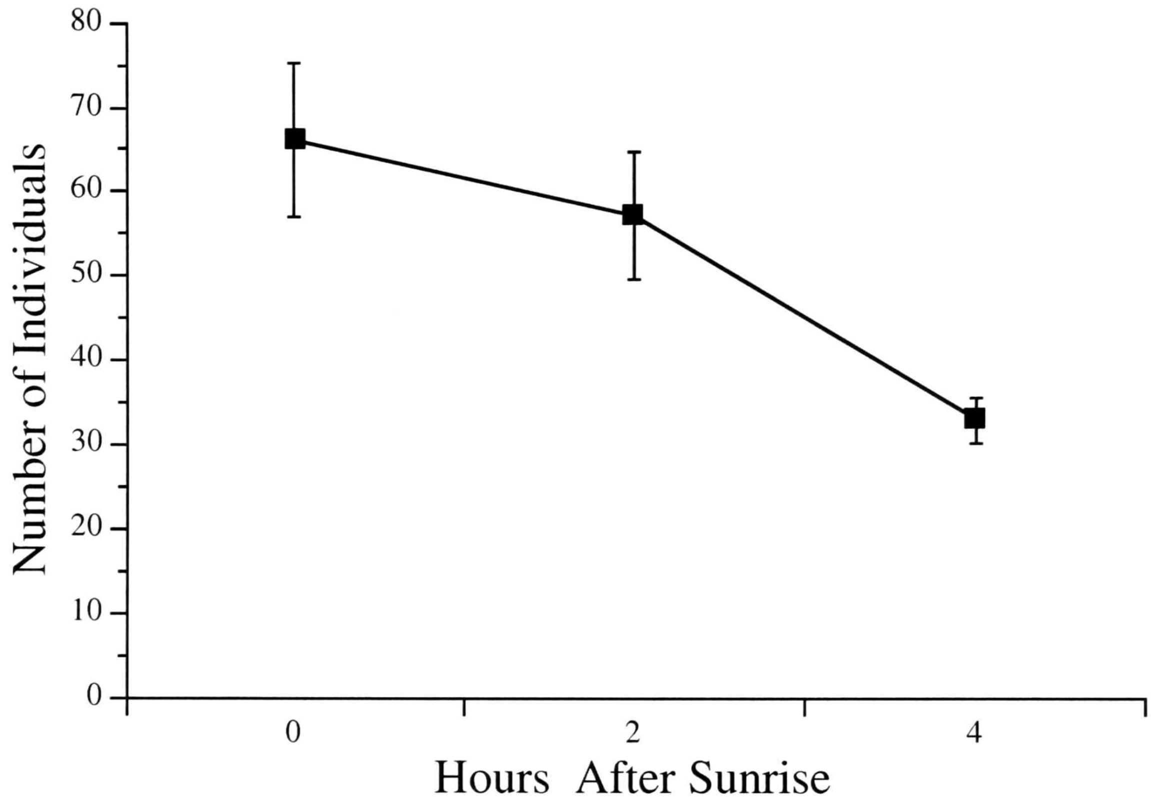

Figure 16. The mean number of migrant individuals (± 1 SE) during the four heaviest days of migration on Kennesaw Mountain during the spring of 1998.

was also variation between years in the number of species detected on Kennesaw Mountain. During 1997, censusing (n = 8 days) detected 48 species of migrant passerines, 42 of which were Neotropical migrants. While censusing during 1998 (n = 10 days) detected 55 species of migrant passerines, 45 of which were Neotropical migrants. A total of 59 species of migrants and 50 Neotropical migrants were recorded on Kennesaw Mountain while censusing during the study period (Appendix). Of the 59 species recorded, 22% have been recorded breeding on Kennesaw Mountain. Of the 22% breeding on the mountain, 31% are known to breed infrequently on the mountain or were detected fewer than 5 times during the study.

Morning flight. - Numerous migrants were observed arriving on Kennesaw Mountain after sunrise. The number of migrants undergoing morning flight was quantified from Kennesaw Mountain during three days in May (Fig. 17). Wind directions during the nights prior to observations varied between 240° - 360° (360°, or 0°, = north), while wind speeds ranged from 0 - 13 km/h (data from Atlanta, Georgia, National Climatic Data Center, NOAA, 1998). Birds typically began to approach the mountain shortly before sunrise, although, most individuals did not arrive until shortly after sunrise. The majority of migrants that I detected arrived at approximately the same elevation as the clearing, or higher, and the peak arrival of migrants occurred within the first hour after sunrise and dramatically declined afterwards. While observations were limited to areas between the east and south, migrants predominantly arrived from the SE and rarely from the east or south. However, birds arriving from other directions could not be detected.

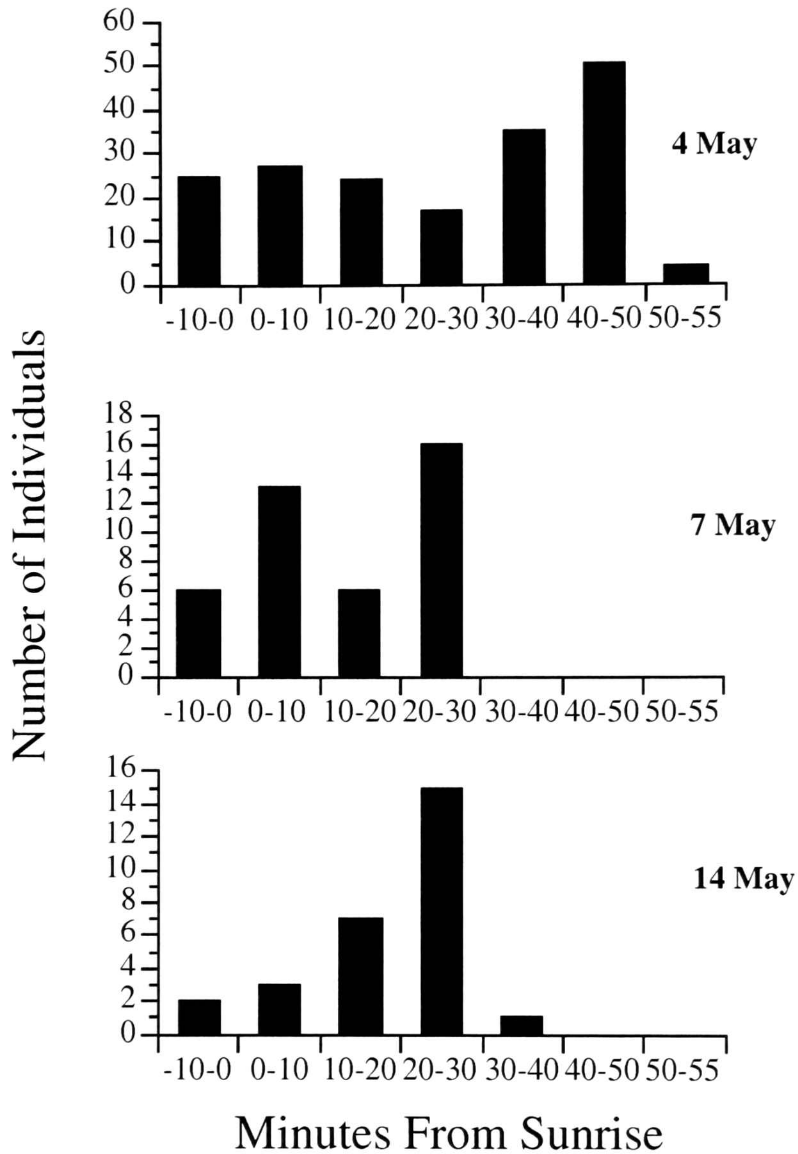

Figure 17. Observations from Kennesaw Mountain of the number of migrants per 10 minute period undergoing morning flight during three days in May 1998. Sunrise occurred at minute zero.

CHAPTER 4
DISCUSSION

Kennesaw, Lost, and Sweat Mountains are located in the upper piedmont of Georgia and are part of a series of isolated peaks along the southern Appalachian Mountain range. These mountains are located approximately 435 km from the Atlantic Ocean and the Gulf of Mexico, and are presumed to lie along an important route for migrating birds. The geographical prominence of these mountains over the surrounding landscape causes them to be particularly conspicuous. This conspicuousness is pronounced from higher elevations with unobstructed views of the mountains. Thus, depending on the weather conditions, these mountains are potentially visible to flying birds for several kilometers. While these mountains would be difficult for migrants to locate during nocturnal flight, they would be easily located during the early morning hours. Therefore, individuals approaching the Appalachian Mountain range while undergoing morning flight might be attracted towards these small, but discernible mountains. Migrants may use mountains such as these as landmarks to help maintain proper orientation during migration, or possibly, to regain proper orientation after displacement during the previous nights migration. Consistent with the idea that migrants are attracted to these geographic features, Kennesaw Mountain has been established as an extremely reliable site for locating large numbers of migrant passerines in the early mornings during migration (Beaton 1995).

Between-sites. - The first question I addressed was whether there was a difference in the number of migrants occurring on each mountain. I found that Kennesaw Mountain attracted the largest volume of migrant birds among the three sites (Figs 7,11). However, Kennesaw Mountain was not unique in attracting a large volume of migrants. In particular, there was no significant difference between the number of migrants occurring on Lost Mountain and Kennesaw Mountain. Meanwhile, Sweat Mountain attracted significantly fewer migrant individuals than the other two study sites. Given the occurrence of migrants at all sites, the variation in the number of individuals occurring on each mountain suggests differences among mountains per se are influencing a migrants' decision to land. Upon approaching one of these mountains an individual may evaluate the habitat suitability which results in their decision to either 1) perceive the habitat is suitable or necessary for stopover and land or 2) determine the habitat is unsuitable or unnecessary for stopover and continue flying until more suitable habitat is found. Because Kennesaw Mountain occurs inside the Kennesaw Mountain National Battlefield Park, which consists of 1168 ha of largely continuous forest, many migrants, and in particular Parulid warblers, appear to perceive the habitat to be suitable for stopover. In contrast, the initial residential development on Lost Mountain and the considerable development already existing on Sweat Mountain has significantly reduced the tracts of continuous forest in these areas. Therefore, arriving migrants may find the habitat less suitable for stopover and may continue flying to more hospitable areas. Thus, the increase in suitable stopover habitat found on Kennesaw Mountain may explain the increase in the number of individuals and species richness detected there in comparison to the other study sites. Therefore, the initial attractiveness of the these sites to migrants may be primarily due to the prominence of each mountain, while the habitat on each mountain has a more secondary role influencing an individuals' decision to land.

Within-sites. - To address this issue further, I attempted to determine whether the use of these sites, and particularly Kennesaw Mountain, was attributable to their geographical prominence or some specific feature of their habitat. As census data indicate (Figs. 7,11) the numbers of migrants on Kennesaw and Lost Mountains are strongly influenced by time of day. Migrants on these two mountains typically began to arrive shortly before sunrise, although the majority of individuals did not arrive until shortly after sunrise. Generally birds continued to arrive during the first couple of hours after sunrise, beyond which time relatively few migrants were observed landing on or passing over the mountains. During mornings with inclement weather the peak arrival of migrants was occasionally delayed up to an hour after sunrise. Upon arrival, migrants formed large, rapidly foraging, mixed-species flocks consisting primarily of Parulid warblers. During days with favorable weather conditions (i.e., light winds and clear skies) these mixed species flocks rapidly dispersed down the mountains into the surrounding lowlands (Fig. 15). This suggests that while migrants are initially attracted to, and do indeed occur on these mountains, during favorable weather conditions they will quickly depart, possibly in an attempt to continue their morning flight. Moreover, during days with less favorable weather conditions (i.e., heavy fog and overcast skies) migrants were much more likely to remain on the mountain and continue foraging throughout the morning (Fig. 15). This implies that while migrants do use the habitat on these mountains for resting and regaining fat supplies lost during the previous nights migration, particularly during periods when weather conditions create poor visibility, the duration of their stopover is short. Therefore, while the habitat on these mountains may be valuable to migrants, they may not necessarily view it as critical for stopover. However, the use of this habitat and the extent to which migrants rely on it is in need of further research.

The implication from censusing data (Figs. 7,11) is that migrants appear to arrive at Kennesaw Mountain during the first few hours after sunrise, forage intensively, and disperse down the mountain throughout the morning. While I did not detect a statistically significant reduction in the number of migrant individuals on Kennesaw Mountain throughout the morning, suggesting migrants are attracted to the mountain due to its habitat, I feel the issue is more complicated than that. Not all migrants seem to be attracted to the habitat on Kennesaw Mountain. While numerous birds were observed landing on Kennesaw Mountain after sunrise, not all migrants acted in this manner. On several occasions migrants approaching Kennesaw Mountain were observed landing on the mountain and promptly departing or continuing their morning flight without stopping at all. These observations are consistent with the aforementioned idea that some migrants approaching these mountains may not perceive the habitat as suitable for stopover or may not be in need of refueling and, therefore, given favorable weather conditions would continue their morning flight. Moreover, these observations lend support to the idea that migrants are initially attracted to these mountains largely due to their prominence. However, the principle attractiveness of these mountains to migratory birds is in need of further research.

Morning flight. - Given that the majority of the nocturnal migrant birds occurring on these mountains arrive within the first few hours after sunrise the role of morning flight becomes an issue. During nocturnal flight birds are potentially subject to displacement from their preferred migratory direction for a variety of reasons ranging from disorientation (Richardson 1982) to wind drift (Gauthreaux 1978; Moore 1990) to the misuse of polar fields. During the morning hours of the migratory season numerous observations have been made of migrants undergoing a diurnal movement known as morning flight (Gauthreaux 1978; Bingman 1980; Hall and Bell 1981; Wiedner et. al 1992; Moore 1990). One hypothesis for the occurrence of morning flight is that migrants are redetermining their correct migratory orientation, or "principal axis of migration", following drift from unfavorable winds during the previous nights migration (Gauthreaux 1978). Evidence for displacement due to wind drift occurs along coastal (Moore 1990) and inland migratory routes (Gauthreaux 1978).

During three mornings in May 1998, I observed numerous migrants undergoing morning flight at Kennesaw Mountain following winds ranging from the west to the north during the previous night (Fig. 17). On all three occasions I observed migrants approaching Kennesaw Mountain from a southeasterly direction. Because many migratory birds are thought to use the Appalachian Mountains for their principal axis of migration and winds ranging between the west and north would disrupt this orientation, these birds have the potential to suffer from wind drift. This, in turn, causes migrants to land in areas to the east of their original orientational route. Therefore, based upon the diagrammatic model set forth by Gauthreaux (1978) the shortest and most logical route for migrants to take to correct for this displacement and redetermine their migratory route would be to undergo morning flight in a northwesterly manner. Observations from Kennesaw Mountain during the spring are consistent with this model.

While the level of dependence on these mountains for critical stopover habitat by migrants is still uncertain, it is quite clear that individuals are attracted to and do utilize the habitat on them (Beaton 1995). Moreover, the wide species richness of neotropical migrants occurring on these mountains, many of which have shown recent population declines (Robbins et. al 1989), emphasizes the need for further investigation of these and other isolated prominent peaks in the southern Appalachian Mountain range. The geographical distinctness of these mountains and their seemingly disproportionate attractiveness to migratory passerines over the surrounding lowlands, particularly

Kennesaw Mountain, may lead us towards locating other similarly attractive inland stopover sites along the southern Appalachian Mountain range. However, comparative data on the abundance of migrant birds in areas of relatively close proximity to these mountains (3-5 km) are needed to ascertain whether the mountains are truly attracting disproportionately larger numbers of birds than the surrounding lowlands. Nevertheless, locations such as Kennesaw Mountain provide us with excellent opportunities to study not only the behavior of migratory birds, but also the intraspecific variation in the timing of migration based upon differences in the ages and sexes of individuals as discussed by Hutto (1998). This in turn will better enable us to prepare more effective conservation programs which will help meet the ecological requirements for birds during migration.

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Appendix. Number of days each species was detected during censusing at each study site. Numbers in parentheses indicate the total number of days each site was censused. Species common names followed by (T) were classified as Temperate migrants, while species common names followed by (NT) were classified as Neotropical migrants.

	Study Site					
	Kennesaw		Lost		Sweat	
	1997 (8)	1998 (10)	1997 (8)	1998 (4)	1997 (8)	1998 (3)
Black-billed Cuckoo (NT) *(Coccyzus erythropthalmus)*	0	1	0	0	0	0
Yellow-billed Cuckoo (NT) *(Coccyzus americanus)*	0	0	2	1	0	0
Chimney Swift (NT) *(Chaetura pelagica)*	2	5	5	3	3	1
Ruby-throated Hummingbird (NT) *(Archilochus colubris)*	1	0	0	0	0	0
Eastern Wood-Pewee (NT) *(Contopus virens)*	2	3	2	1	0	0
Acadian Flycatcher (NT) *(Empidonax virescens)*	0	1	0	0	0	0
Great Crested Flycatcher (NT) *(Myiarchus crinitus)*	2	0	7	3	6	2
Eastern Kingbird (NT) *(Tyrannus tyrannus)*	0	1	0	0	0	0
White-eyed Vireo (NT) *(Vireo griseus)*	3	2	5	0	0	0
Yellow-throated Vireo (NT) *(Vireo flavifrons)*	4	1	2	1	0	0
Blue-headed Vireo (NT) *(Vireo solitarius)*	3	3	2	1	3	0
Red-eyed Vireo (NT) *(Vireo olivaceus)*	7	9	8	4	5	1

Appendix. Continued.

Purple Martin (NT) *(Progne subis)*	1	1	4	1	2	2
Tree Swallow (NT) *(Tachycineta bicolor)*	1	1	0	0	0	0
Barn Swallow (NT) *(Hirundo rustica)*	0	1	0	0	0	0
House Wren (NT) *(Troglodytes aedon)*	3	2	1	0	0	0
Winter Wren (T) *(Troglodytes troglodytes)*	0	2	0	1	0	0
Ruby-crowned Kinglet (T) *(Regulus calendula)*	4	6	2	1	3	1
Blue-gray Gnatcatcher (NT) *(Polioptila caerulea)*	8	7	3	1	1	1
Veery (NT) *(Catharus fuscescens)*	2	3	1	1	0	0
Swainson's Thrush (NT) *(Catharus ustulatus)*	3	3	0	0	0	0
Hermit Thrush (T) *(Catharus guttatus)*	0	1	0	0	1	0
Wood Thrush (NT) *(Hylocichla mustelina)*	5	2	3	0	3	1
American Robin (T) *(Turdus migratorius)*	0	0	0	0	1	0
Gray Catbird (NT) *(Dumetella carolinensis)*	3	2	0	0	0	0
Cedar Waxwing (T) *(Bombycilla cedrorum)*	3	6	0	2	1	0
Blue-winged Warbler (NT) *(Vermivora pinus)*	2	0	2	0	0	0
Orange-crowned Warbler (NT) *(Vermivora celata)*	2	0	0	0	0	0

Appendix. Continued

Nashville Warbler (NT) *(Vermivora ruficapilla)*	1	1	0	0	0	0
Northern Parula (NT) *(Parula americana)*	0	4	0	0	0	0
Chestnut-sided Warbler (NT) *(Dendroica pensylvanica)*	3	3	1	1	0	0
Magnolia Warbler (NT) *(Dendroica magnolia)*	2	4	1	1	1	0
Cape May Warbler (NT) *(Dendroica tigrina)*	1	1	0	0	0	0
Black-throated Blue Warbler (NT) *(Dendroica caerulescens)*	3	6	3	2	2	0
Yellow-rumped Warbler (T) *(Dendroica coronata)*	6	8	5	3	6	2
Black-throated Green Warbler (NT) *(Dendroica virens)*	6	8	5	2	3	0
Blackburnian Warbler (NT) *(Dendroica fusca)*	5	3	3	2	1	0
Yellow-throated Warbler (NT) *(Dendroica dominica)*	0	1	0	0	0	0
Pine Warbler (T) *(Dendroica pinus)*	0	0	8	4	2	0
Prairie Warbler (NT) *(Dendroica discolor)*	4	1	1	1	0	0
Palm Warbler (NT) *(Dendroica palmarum)*	4	6	2	2	2	1
Bay-breasted Warbler (NT) *(Dendroica castanea)*	1	3	1	0	1	0
Blackpoll Warbler (NT) *(Dendroica striata)*	3	5	2	1	1	0
Cerulean Warbler (NT) *(Dendroica cerulea)*	4	4	3	0	0	0

Appendix. Continued.

Black-and-white Warbler (NT) *(Mniotilta varia)*	5	7	7	3	8	3
American Redstart (NT) *(Setophaga ruticilla)*	1	6	1	1	0	0
Worm-eating Warbler (NT) *(Helmitheros vermivorus)*	3	5	2	2	0	0
Ovenbird (NT) *(Seiurus aurocapillus)*	6	7	6	1	6	3
Kentucky Warbler (NT) *(Oporornis formosus)*	2	2	2	1	0	0
Common Yellowthroat (NT) *(Geothlypis trichas)*	2	1	0	0	0	0
Hooded Warbler (NT) *(Wilsonia citrina)*	7	9	6	3	3	1
Canada Warbler (NT) *(Wilsonia canadensis)*	1	2	0	0	0	0
Yellow-breasted Chat (NT) *(Icteria virens)*	0	1	0	1	0	0
Summer Tanager (NT) *(Piranga rubra)*	8	8	5	2	3	2
Scarlet Tanager (NT) *(Piranga olivacea)*	3	7	7	3	1	2
White-throated Sparrow (T) *(Zonotrichia albicollis)*	7	9	4	1	0	1
Dark-eyed Junco (T) *(Junco hyemalis)*	0	1	0	0	0	0
Rose-breasted Grosbeak (NT) *(Pheucticus ludovicianus)*	4	7	1	3	1	0
Indigo Bunting (NT) *(Passerina cyanea)*	6	7	3	2	1	0
Brown-headed Cowbird (T) *(Molothrus ater)*	3	2	3	1	0	0

Appendix. Continued.

Pine Siskin (T) *(Carduelis pinus)*	0	3	0	1	0	0
American Goldfinch (T) *(Carduelis tristis)*	6	9	6	4	5	3